International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 5, July-August 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

LAN Based HF Radio Simulator: An Approach to Develop an Early Prototype for Long-Distance Radio Communication

Md Rajib

Department of CSE, Military Institute of Science and Technology (MIST), Dhaka, Bangladesh

ABSTRACT

Communication is considered one of the most decisive factors in winning a battle. That's why every nation is very well focused to enhance its communication facilities. High Frequency (HF) radio communication system is a major communication platform used for long-distance communication not only for the military forces but also for the law enforcing agencies across the globe. As these communication paraphernalia are very erudite, sophisticated and costly, therefore, rough handling of them during the training period may create a lot of wear and tear. As a result, the equipment loses its capability to work perfectly during actual need. Therefore, an endeavor has been made through this paper to develop LAN-based simulation software for HF radio sets commonly used by varied combat forces and law enforcement agencies. In the order of discussion, both qualitative and quantitative analyses have been carried out through varied graphical illustrations. Various online resources, government publications, administrative census were consulted as primary and secondary data sources. This simulator-based proto-type software will facilitate the use of HF Radio equipment to have vigorous practice and necessary test and trial without deploying the Radio sets on the ground and lessen the wear and tear as well.

KEYWORDS: *LAN, HR Radio, Simulation Combat Communication, Operational Efficiency*

How to cite this paper: Md Rajib "LAN Based HF Radio Simulator: An Approach to Develop an Early Prototype for Long-Distance Radio Communication" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-5, August 2021, pp.1217-1227, URL: www.ijtsrd.com/papers/ijtsrd45034.pdf

IJTSRD45034

Acronyms

Lan- Based HF Radio Simulator:	LHRS
High Frequency	HF
User Interfaces	UI
Double Cut and Join	DCJ
Block Interchange	BI
Synteny Block	SB

INTRODUCTION

1. Nowadays, most of the developed nations are exploring array processors and digital signal processing technologies to develop real-time, software-based test equipment that simulates high-frequency (HF) radio links. This system is usually known as an HF Channel Simulator like Floating Point Systems AP-120B array processor-based HF radio simulator with wide-ranging bandwidth capabilities and great flexibility in the selection of link parameters available to the user[1] All distortions are at least 50 dB below the desired signal output level. However, these simulators are very expensive.
2. In this paper, an endeavor has been made to develop a user-friendly software-based High Frequency (HF) Radio simulator and trainer of radio sets with affordable cost employing simple algorithm through which persons can practice varied features of widely used HR radio sets at any time. The software will have all the basic functionality of a radio set. The communication will be established through LAN. The basis of the communication will be restricted within Half Duplex mode which is more frequently used in combat communication. Using this LAN-based HF Radio Sumlator(LHRS), the person will have a real-life experience of using a radio set within the actual operational scenario. For a newbie[1] an inexperienced newcomer to a particular activity while handling a particular kind of HF radio set for the first time, should not provide complete access to configure the entire operating modules of that radio set. Rather, if someone can have a complete orientation on varied operating

features of a particular HF radio set through any simulator-based platform, it will certainly be more beneficial for him before handling the actual equipment on the ground. Since all the latest HF radio sets are fairly expensive and abstemiously sensitive encompassing cutting-edge technology, therefore, it will not be prudent to hand over these affluent communication assets to the greenhorns' operator for practicing. In another perspective, we can say that most of the members of the armed forces are not able to get ample real war experiences in their lifetime. Therefore, in case of emergency, problems might arise. So to mitigate the issues we can give them war alike experiences and tasks to make them battle-ready through the proposed prototype HF radio Simulator shortly termed as "LHRS"

3. **Scope of The Study** Scope The scopes of LHRS are as follows:

3.1. To lessen the exhaustive physical use of the original HF radios for training purposes

3.2. To enhance the training options and dynamics. Facilitate to conduct simulator-based training without the radio sets.

3.3. To simplify the training procedures of varied kinds of HF radio and bringing them under the same platform.

3.4. To incorporate a performance evaluation database and keep track record of performance of the operator as well as field test results conducted in different scenarios

4. Objectives The objectives of Radio Equipment Simulator and Trainer are as follows:

4.1. To identify the requirements of using an HF radio simulator.

4.2. To develop a simulator compatible with widely used HF the radio sets

4.3. To formulate technical and operational simulations.

4.4. To establish communication within HF radio sets working under the same LAN.

Methodology

5. The methodology is illustrated in the figure-1 below. In this study, an endeavor has been made to implement only basic SRS and USR with limited GUI features. A comprehensive effort is needed to implement the proposed simulator with inclusive SRS and cosmic GUI features. This process also necessitates involving all expert personals(Vendors of Radio sets, System designers, Coders, Combat Communication Engineers, etc).The methodology of the study is illustrated in figure-1 below:

User Requirement Specification	CRS
Software r Requirements Specification	SRS
Graphical User Interface	GUI
System Usability Scale	SUS

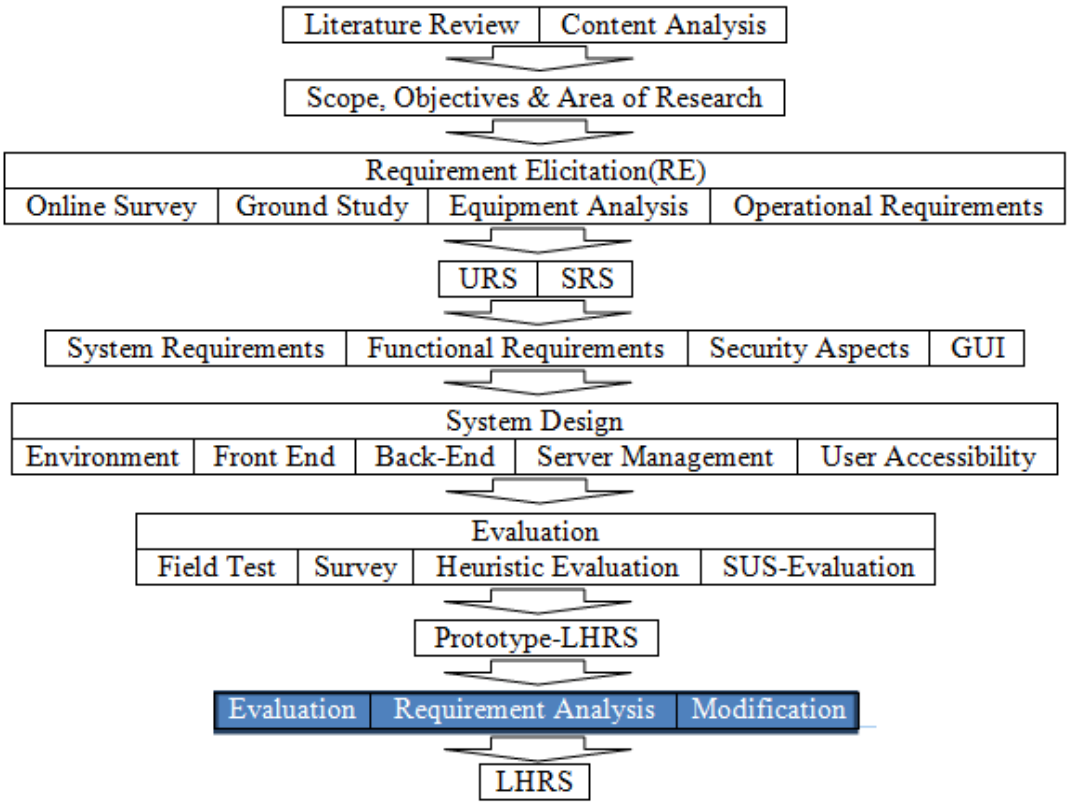


Figure-1: Methodology

Literature Review

6. The aim and intent of this literature review are to explore and analyze the previous works on varied software-based radio simulators. In the paper[1], L. G. Anderson proposed three algorithms based VHF radio set simulator. In [2], the researcher developed an HF radio simulator on a voice band radio. The simulator was made for operating in a single mood (Simplex mode).In [3], T.C Gills and I. Willoughby made an effort to evaluate the viability of creating Ground to Air VHF radio simulator. In the overall implementation process, they tried to use "Gaussian Power Spectrum Assumption" and Tap Gain Independence Assumptions which was a great leap forward in the sector of radio simulators. The further illustration on literature review emphasizing relevant factors are appended in table-1 below:

6.1. Table-1: Significant Finding from Literature review

Reference	Arena of Research	Objective and Methodology	Result/Outcome
[4]	1.Cognitive Radio Networks(CRN) 2.Spectrum sharing techniques	To formulate the architecture of CNC with spectrum sharing	Different simulators can be brought in the same platform
[5]	1.Signal Process Modelling 2.Software packages, 3. Simulation history	To outline the generalized perspective and methods of Radio Communication System(RCS) simulation	A total study to develop the history of radio communication simulation
[6]	1.Software Simulator, 2.Radio Communication	To develop a system that can pave the way to begin a simulation	A general approach has been defined to create the simulation
[3]	1.Voice Band Channels	To design simulators for different voice band channels	Four methods are discussed to implement the simulators.

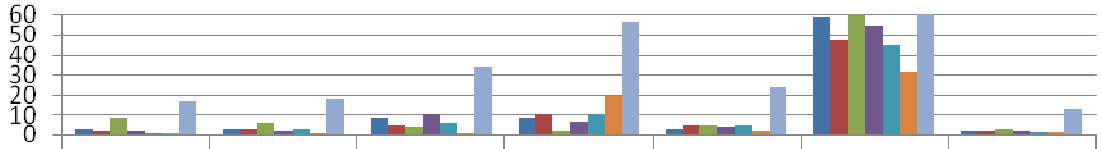
Table-1: Significant Finding from Literature review (Source: Authors' Self-Construct)

Requirement Elicitation

7. XXX. Requirement Elicitation also serves as a basis for preparing system attributes and various UI of software used as GUI in proposed LRHS as intended. In addition,a comprehensive requirement elicitation will also explore the scope and situations while practical use of radio equipment and to reveal the features that need to be incorporated for developing a system to simulate the radio equipment which can be a trainer too.

7.1. **Users' Requirement Specification** An exhaustive survey (with both open and close-ended questionaries) was conducted through an online survey platform (Google form) to identify the users' requirement specifications. Twenty-five combat communicators participated in this regard. The evaluation and output analysis was carried out through a weighted Matrix Method within a range of 5(four) marks where Strongly agree(SA) is allotted with 5 marks. Subsequently Agree(A), Neutral(N), Disagree(DA) Strongly Disagree(DA) are allotted with4, 3,2 and 1 marks respectively. In addition, users' general comments and observations on wide-ranging issues were collected and ensured via emails The glimpse of survey analysis is illustrated in subsequent paragraph(7-8), and Graph-X to Yis given below:

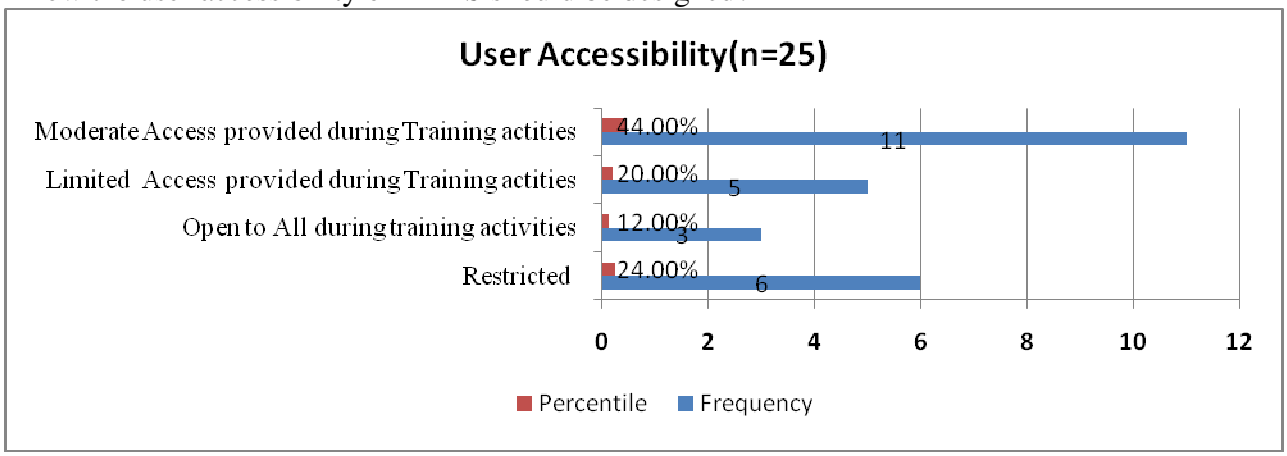
7.2. For which purpose you are normally using radio sets?(Within a month)



	5>=	4>=	>=3	>1	0	Total Usage	Avg Usage
Oprtational Activities	3	3	8	8	3	59	2.36
Field Test	2	3	5	10	5	47	1.88
Practise	8	6	4	2	5	78	3.12
Training Activities	2	2	10	7	4	55	2.2
Administration	1	3	6	10	5	45	1.8
Any Other	1	1	1	20	2	32	1.28
	17	18	34	57	24	316	12.64

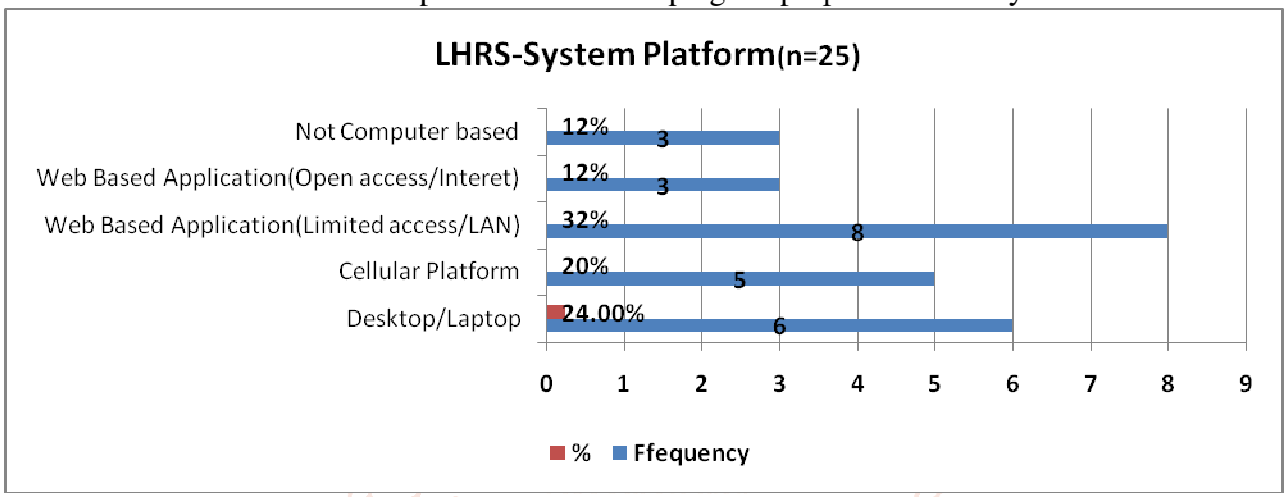
Graph-1: Purpose of using HR radio sets(Source: Survey Question-1)

7.3. How the user accessibility of LHRS should be designed?



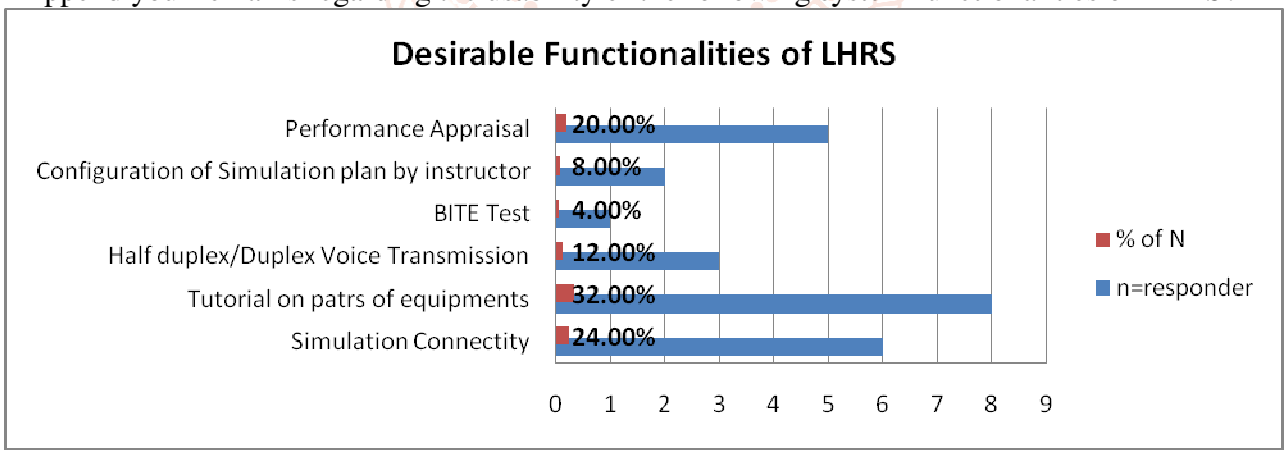
Graph-2: Opinion of the responders on limits of System accessibility (Source: Survey Question-2)

7.4. What will be the most suitable platform for developing the proposed LHRS system?



Graph-3: Opinion on selecting an apposite platform for the proposed system(Source: Survey Question-3)

7.5. Append your remarks regarding the usability of the following system functionalities of LHRS?



Graph-4: Opinion on varied system functionalities of LHRS(Source: Survey Question-6)

7.5.1. **Outcome of the Survey Analysis** The findings from the above-stated surveys (closed ends questionaries) as well as some Key Personals Interviews (open-end questionaries) are appended below:

7.5.2. **Expedient Issues**

7.5.2.1. All most all users opined that the inception of LHRS would facilitate overall training and operational activities to a greater extent(average usage 5 times/months/person; in around 40% of total usage/months;graph-1)

7.5.2.2. The bringing of radio equipment under a similar platform(Web-based 44%) meant very helpful in developing countries' perspectives.(Graph-3)

7.5.2.3. Adaptation seems to be difficult in the preliminary days, but incessant use can make it feasible.

7.5.2.4. The system should be restricted to limited users providing moderate accessibility during training hours(44% of total respondents, Graph-2)

7.5.3. **Constraints** Some constraints which have been defined can be stated as follows:

7.5.3.1. Parallel operation with the existing system.

7.5.3.2. Only after efficacious trials, the new LHRS system can be incorporated along with the present conventional one.

7.5.3.3. Strong security must be provided against all types of security breaches.

7.5.3.4. Hardening User accessibility may provide less flexibility in training aspects.

7.5.3.5. The GUI of LHRS should be user-friendly, flexible, easy to use, and restrict with necessary functionalities only.

7.5.3.6. The software system must be compatible with the present conventional system.

7.5.3.7. Test and Trial on functionality test can not be performed if communication assets are working under separate LAN.

7.5.4. **Dependencies** Following dependencies have been found while going through the user requirements:

7.5.4.1. Login system should be made first before all other related systems.

7.5.4.2. Login system must have some identification factor to identify between admin and user.

7.5.4.3. Admin dashboard should be made before the user dashboard.

7.5.4.4. The system should be compatible with any browser and also compatible with mobile phones, tablets, and any handheld smart devices.

7.5.4.5. Easy and simple interface as the soldiers with various backgrounds might be using it.

7.5.4.6. Easy report and output design. 12 7. The system processing time must be small to make it faster and effective. 8. To make communication, need to be connected under same LAN.

Software Requirements Specification (SRS)

8. The SRS in light of survey and content analysis and in-depth requirement elicitation are illustrated in table-2 below:

System Requirements	User Requirements	Functional Requirements
1. Identical Interface for selecting available HF Radio series 2. Mode selection Option(Simplex/Half Duplex) 3. Scenario based Selection Option(Adverse weather effect/ Inerception/Jamming) 4. User's authentication Pannel 5. Separate admin panel 6. Users Portal 7. Central Database 8. Low Power Consumption 9. Portability	1. Facilitate users to have real-time practice on varied operation modes, BITE, system configuration portal on various king f HF radio sets. 2. Preserve track record of practice and test& trial 3. Facilitate Instructor to take the practical exam on LHRS based on the varied operational and atmospheric scenario 4. GUI needs to be as like as actual radio sets.	1. Details of operations conducted on every screen. 2. Metaphors of system reports. 3. Facts and figures regarding the comprehensive operational flow chart/diagram of LHRS 4. Allow flexibility in operation and data handling(create/modify/delete system data) 5. Automatic System Data Retrevation /Playback 6. Enlist and Maintain Simulation Plans 7. Monitoring and Assigning Task 8. Update Information

Table-2: Software Requirements Specification (SRS) of proposed LHRS

9. In addition, an in-depth analysis has been carried out to further categorized the SRS into Functional and non-functional requirements. Details are illustrated in table-3below:

Ser	SRS	Type of Requirements	
		FR	NFR
1.	The ability of LHRS to provide individual users personal performance updates?	√	
2.	Identification of individuals user's strengths and weaknesses?	√	
3.	LHRS should enlist and maintain simulation plans	√	
4.	Allow admin to monitor and assign specific tasks goals	√	
5.	Register and update users information,	√	
6.	Detail Performance appraisal of Users with an unaltered track record	√	
7.	Access Control System		√
8.	Varied Modes of Operation (Simplex & duplex)	√	
9.	Set Conditional based operational environment (Topological and weather Effect, Hostile EW activities)	√	
10.	Separate panel for user and Administrator	√	
11.	follow legal and compliance rules		√
12.	Ensure the reliability, availability, and performance of the software system		√
13.	Ensure satisfactory UX and ease of operating the software.		√
14.	Formulating the security policy of the software system.		√

Table-3: SRS vis a vis Functional and Non-functional Requirements(Source: Authors' Self Construct)
Notes: FR=Fuctional Requirements, NFR= Non Functional requirements

Designing Phase of LHRS: Software and UI

10. Software Design is the process of specifying a software artifact when it is created. This process is envisioned to undertake implementation purpose and goals utilizing varied embryonic components and substance constraints. In this study, two approaches were followed termed as "Physical Data Flow scheme " and "Logical Data Flow scheme". The simple three-step operationalization flowchart of LHRS is illustrated in figure-3 below:

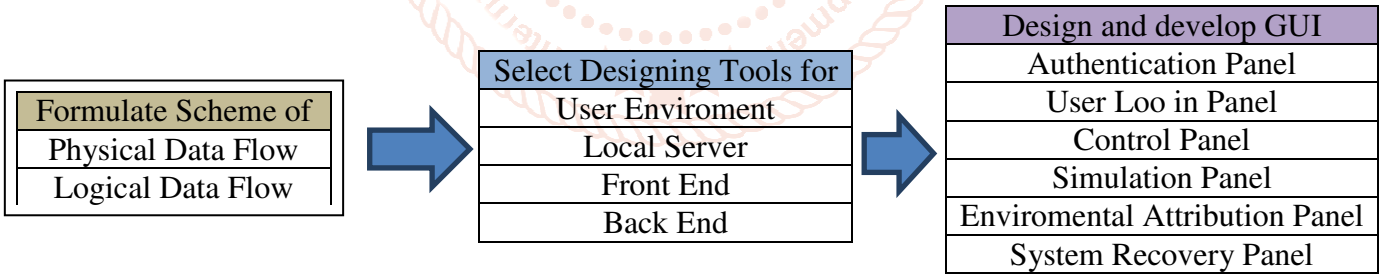


Figure-2: Operationalization Diagram of LHRS
(Source: Authors' self-construct)

11. **Physical and Logical Data Flow Diagram** A physical data flow diagram characterizes the physical modules with necessitating properties required to fabricate the overall system. On contrary, A logical data flow diagram establishes the necessary link among those physical components. The physical and logical data flow diagram of proposed LHRs are illustrated through figure-3 and 4 respectively:

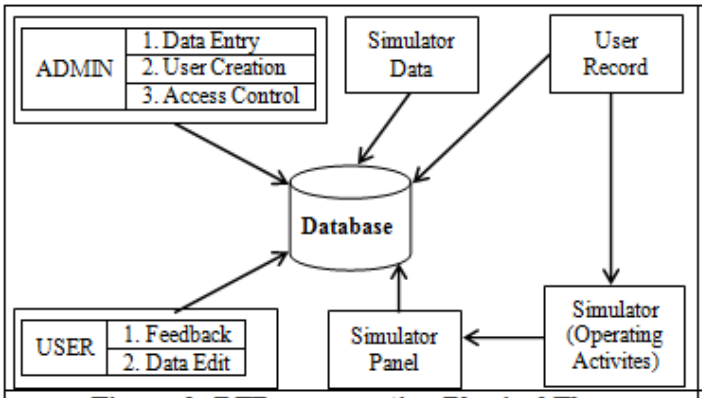


Figure-3: DFD representing Physical Flow

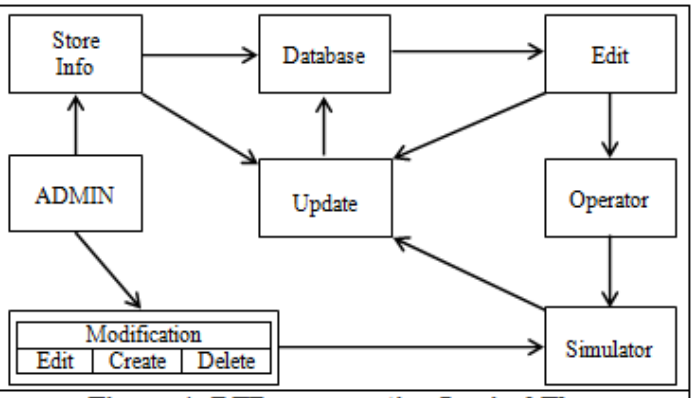


Figure-4: DFD representing Logical Flow

12. **Designing Tools** In the design part, picking up apposite tools is very crucial. After the appropriate tools have been designated, the system engineer/ program writer may start working with the implementation phase. The tools and environment of the proposed LHRS are described below:

12.1. **Environment** Environment represents the platform on which the system will be functionalized. The Since LHRS will be a web-based application and LAN supported, therefore, it must support cross-platform usability. Web-based applications will facilitate in achieving flexibility and make the simulator more user-friendly

12.2. **Local Server** As it is a prototype project study, therefore, local servers have been utilized. In LHRS, XAMPP is utilized as the server which is free and open-source cross-platform encompassed with stack package. The XAMPP creates the database locally which can store the required information about ongoing operations. XAMPP stores in the local test server.

12.3. **Front-End** Front-end denotes the GUI that permits accessing tabular, structured, or raw data stored within it. It deals with utility data as well as users' requests. The front end of the software has been made of two applications; Laravel and Vue.js. Laravel is a PHP framework. It is based on MVC architecture. It is a collection of methods, classes, or files that the programmer use. The interface of the software is made by laravel. On the other hand, **Vue.js** is used to develop the interface of the simulator. When a user will enter the simulator portion, then the interface of the simulator which is made by Vue.js will appear.

12.4. **Back-End** Back-end is normally denoted as the part of a computer application or code itself that permits the entire system to be operational which cannot be accessed by the user. It acts as a backbone of the entire system and processes all sorts of necessary requests to make the system functional. These are the server-side of the application. In LHRS, MySQL, and PHP are utilized to develop the back end.

Overview of GUI

13. LHRS has two different segments basing on the user (Admin and General User). An admin user owns necessary attributes to hosts the overall whole authority(ie creating new users, changing and updating user information, assigning tasks, permission to the user as and when required). He is also having the authority of assessing the performance of general users/operators. On contrary, the general user has limited access and can use the system for simulation, track his performance, recording the simulation, performing various tasks assigned to him. The system has been developed chronologically in light of constraints and dependencies. Few snapshots on GUI of -LHRs are shown in figure(5-10) below:

Figure 5: Login Page

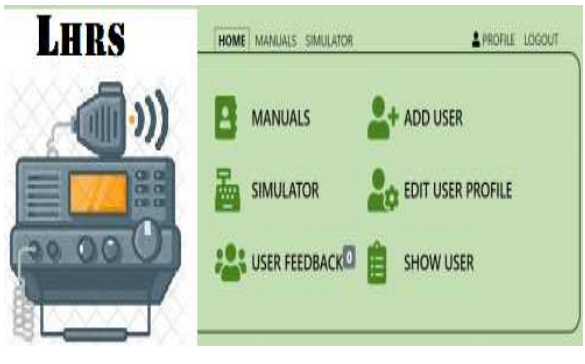


Figure 6: Admin Panel

Figure 7a: Adding a User

Figure 7b: Editing data of a User

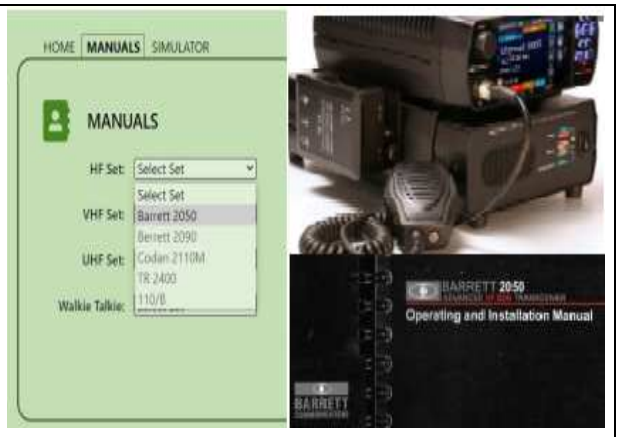


Figure 8: Manual Selecting Interface

Figure 9: Simulator Selecting Interface

Figure 10: Simulator Interface

System Evaluation

14. Evaluation denotes the most crucial part of system development. After the development is done, evaluating the system with the basic criteria of a system is important. It is needed to check that whether the software has reached a minimum standard or not. Furthermore, it also needs to be clarified that, whether the requirements which were stated earlier bythe user have been met or not. In this study, two types of evaluation methods have been utilized to findout the overall functionality, usability, and UX of the proposed LHRS:

14.1. Subject Matter Expert(SME).
14.2. System Usability Scale(SUS).
14.3. Nelson's 10 Heuristic Principles.

15. **Subject Matter Expert** "A subject-matter expert (SME) is a person who is an authority in a particular area or topic"[9]. "In case of developing a system or project, for evaluation; the system or project is taken to an expert who has a vast knowledge about his field"[10].He can understand the system better, evaluating and comparing it with the present system available. Some criteria are settled in advance on which the overall evaluation and testing need to be carried out. Those criteria are listed and SME's are asked to compare between the current system and the developed system. In this study, the following criteria are considered, and based on these verdicts were taken from relevant SMEs. The brief SME analysis is shown in table 2 below:

Criteria	SME in Actual Scenario	SME in Developed System
Time	High	Low
Resource	Various Connections required	Full digital
Data Storage Capacity	No	Yes
Expertise Level Required	High	Low
Miniature Observation Capacity	Cannot be possible	Possible
Integration viability	Complex procedure	Easier
User Flexibility	Need a high level of effort to operate	Easy to operate
Data Security	Less	High
Error Probability	Mismatch Problem	Less

Table 4: SME Evaluation

16. **System Usability Scale**

16.1. In systems engineering, the system usability scale (**SUS**) is a simple, ten-item attitude Likert scale giving a global view of subjective assessments of usability"[11].Generally, is a scheme of measuring the efficacy of software. Furthermore, "it has several different aspects: mentionable; effectiveness (can users successfully achieve their objectives), efficiency and satisfaction."[12].

16.2. **Calculation Method** The techniques mainly follow the weighted Matrix method(as mentioned in paragraph 6.2)overall calculation method of this technique are as follows:

16.3. **SUS Questions** The Questions that were asked during the SUS stated below:

16.3.1. Do you think that you would like to use this system frequently?

16.3.2. Do you found the system unnecessarily complex?

16.3.3. Do you think the system was easy to use?

16.3.4. Do you think that you would need the support of a technical person to be able to use this system?

16.3.5. Do you find the various functions in this system well integrated?

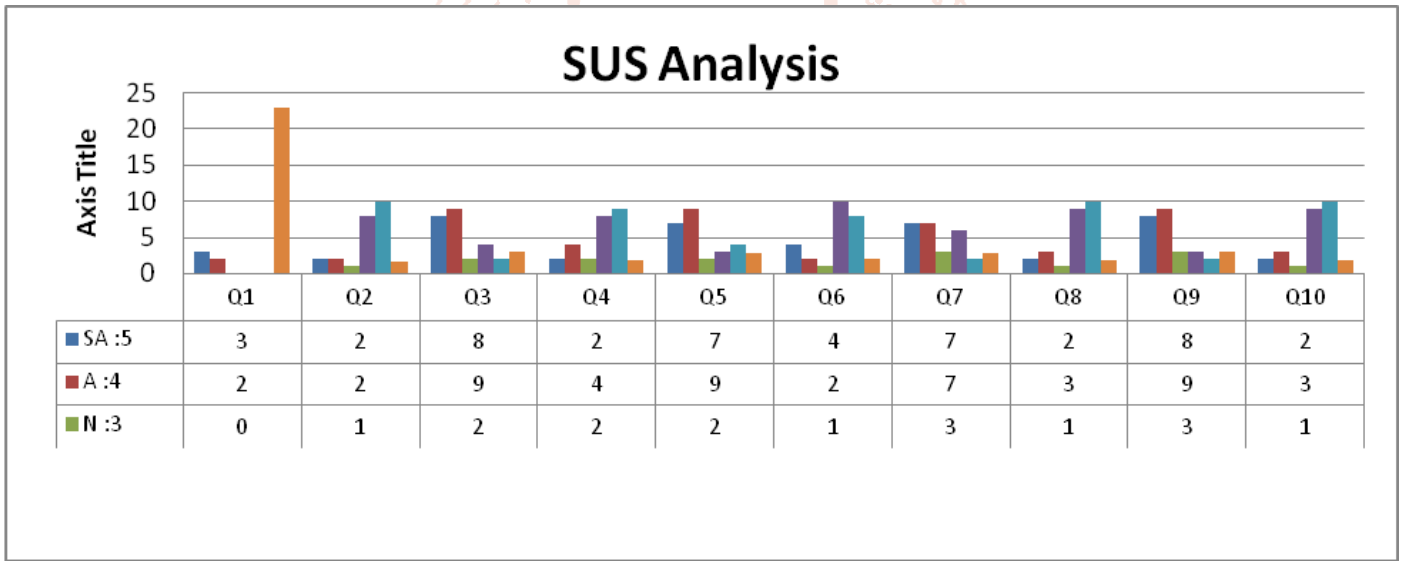
16.3.6. Do you think there was too much inconsistency in this system?

16.3.7. Do you think that most people would learn to use this system very quickly?

16.3.8. Do you find the system very cumbersome to use?

16.3.9. Do you feel very confident using the system?

16.3.10. Do you need to learn a lot of things before you could get going with this system?



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
SA :5	3	2	8	2	7	4	7	2	8	2
A :4	2	2	9	4	9	2	7	3	9	3
N :3	0	1	2	2	2	1	3	1	3	1

Graph-5 SUS Analysis(Frequency Distribution based)

16.4. **SUS Analysis**

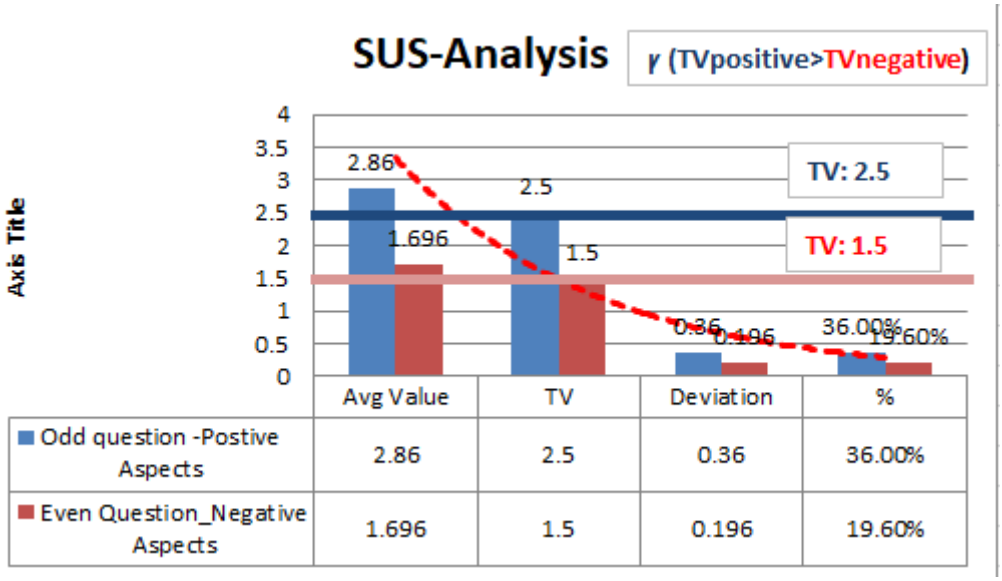
16.4.1. Odd question (Q1,Q3…Q9) denotes the positive aspects/factorsonthe usability of proposed LHRS which average value is 2.86. [Graph-x]

16.4.2. Even question (Q1,Q3…Q9) denotes the negative aspects/factors on the usability of proposed LHRS which average value is 1.69. [Graph-x]

16.4.3. The threshold value (sustainment factor value) of proposed system are selected as 2.5 for Odd questions (positive factors) and 1.5 for even quentions (Negative aspects). [Graph-y]]

16.4.4. The deviation between two aspects results in the Usability of the proposed system. In this analysis deviation of positive aspects (0.36)> than negative aspects (.196). [Graph-x]

16.4.5. Therefore the system usability [1-(0.36-0.1960] =.88 or **88%]** is quite good. [Graph-x]



Graph-6 : Outcome of SUS Alalsis

17. **Heuristic Evaluation**

17.1. In this study Nelson's Heuristic Evaluation is carried out to further confirm the usability of the proposed system.

17.2. 10 Heuristic Principles of Nelson are illustrated with frequency distribution(responders'r respondent) in table 4 below:

Criteria	User 1	User 2	User 3	User 4	User 5	Total
Visibility of system status	1	1	1	1	1	5
Match between system and real world	1	1	1	1	1	5
User Control and Freedom	1	1	0	1	1	4
Consistency and Standards	1	1	1	1	1	5
Error prevention	1	1	1	0	1	4
Recognition rather than recall	1	0	1	1	1	4
Flexibility and Efficiency of use	1	1	1	1	1	5
Aesthetic and minimalist design	0	0	1	0	0	1
Help users recognize, Diagnose and recover from errors	1	1	1	1	1	5
Help and documentation	1	0	1	1	1	4
Total	9	7	9	8	9	42

Table-5 Heuristic Evaluation (Nelson's Heuristic principal)

17.3. ***Findings***

The findings which we can gather after the evaluation of the web-based application after applying Nelson's 10 Heuristic Principle are as follows:

17.3.1. All the Users have evaluated the UI as efficient and functional maintaining most of the heuristic having an average

17.3.2. Most of the users (4 out of 5) have thought the UI has room for improvement in the case of aesthetic design.

17.3.3. Few Users (2 out of 5) have commented about the help documentation.

Conclusion

18. Harris Corporation had developed tactical HF radios, an apposite medium for combat wireless voice communication networks just before WWII using standard Internet protocols. "Although HF radio links own numerous unique characteristics, HF wireless subnets are inclined to many of the same traffic flow characteristics [13]. and topologies as existing in line-of-sight (LOS) radio networks, giving rise to similar unfavorable issues for transmission which impart themselves to investigation through simulation."[14]. Consequently, an endeavor has been taken to develop a LAN-based HF Radio Simulator in short "LHRS" which is quite efficient and high-

fidelity to examine various aspects of HF radio communications.

19. "HF band usually depend on solar radiation characteristics, time of day and seasonal variations which are almost unpredicted indeed."[15] Therefore, some sorts of simulation devices for HF radio communication are of utmost essential for every military institution for near-real-time propagation sensing and frequency adaptation.

20. **Future Scopes** Development scopes in impending times are always available. A project-based study will always possess gray areas as well as possibilities and opportunities for further development works. arenas that can be traversed to help the project reach a new height. Future scopes are such a part of the project which is researched later on and advancement can be made if that 36 research is successful. Therefore, like others, this project-based study is also in possession of future scopes to work on in varied dimensions. Firstly, implementing all functionalities of radio equipment. Secondly, as only one radio set is implemented till now, so the inclusion of all other types of HF radio equipment (Ie Codan series HF) can be done. This will stretch the horizon of the proposed system.

References

[1] L. G.Anderson, "A simulation study of some dynamic channel assignment algorithms in a high capacity mobile telecommunications system," IEEE Transactions of Communications, vol. 21, no. 11, pp. 1294–1301, 1973.

[2] J. F. J. M. Leonard Ehrman, Leslie B.Bates, "Real-time software simulation of the hf radio channel," IEEE Transactions of Communications, vol. 30, no. 8, pp. 1809–1817, 1982.

[3] I. W. Timothy C Giles, Simulation of High-Frequency Voice Band Radio Channels. thesis, Defence Science and Technology Organization, 1993.

[4] D. Workgroup, "Tactical communication simulation system," 2020.

[5] J. A. Delgado-Pen´ın, Radio Communication Systems simulation: from the pioneers to the present. PhD thesis, Universitat Politecnica de Catalunya. UPC BarcelonaTECH. Campus Nord, 2015.

[6] Z. A. Shriram K Vasudevan, Sivaram R, "Software-defined radio implementation (with simulation analysis)," International Journal of Computer Applications, vol. 4, no. 8, pp. 21–27, 2010.

[7] X. L. K. Z. Qi Dong, Yu Chen, A Survey on Simulation Tools and Testbeds for Cognitive Radio Networks Study. Ph.D. thesis, George Mason University, 2018.

[8] https://en.wikipedia.org/wiki/Subject-matter_expert.

[9] ibid.

[10] https://en.wikipedia.org/wiki/System_usability_scale.

[11] ibid.

[12] Traffic-flow characteristics such as flow, density, and space mean speed (SMS) are critical to Intelligent Transportation Systems (ITS).

[13] J.Weston and E.Koski, "High-Frequency Radio Network Simulation Using OMNeT++", Proceedings of the "OMNeT++ Community Summit 2015, Harris Corporation- Rochester, NY, USA.

[14] ibid